Public Preferences for Hydrogen Buses in London: Comparing OLS and Quantile Regression Approaches

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Abstract

Using the contingent valuation method, this study investigates public willingness to pay for the air and noise pollution reductions of hydrogen buses in London. Values elicited using three different payment vehicles include: 27p on top of standard 70p bus fare, £5.57 extra monthly bus fare and £30.23 extra yearly tax. Overall, ordinary least squares regression (OLS) estimates indicate that the influence of independent variables on the fare-based payment mechanisms is very small. Quantile regression results however show that 1) variables that were not significant in the OLS regression are actually significant at certain quantiles along the willingess to pay distribution, 2) the effect of independent variables on willingness to pay vary significantly along its distribution, and also between payment vehicles. These findings suggest that classical least squares estimation is complemented by quantile regression methods for analysing willingness to pay data.

Keywords: hydrogen, contingent valuation, quantile regression

Introduction

1.1 Background

Road transport is currently responsible for 22% of all UK carbon dioxide emissions, and this figure is expected to rise a further 18% between 1996 and 2010 (DUKES, 2001). Growing concerns about climate change and urban air quality have highlighted the need to initiate a shift towards emissions-free transport fuels and technologies. Hydrogen, currently one of the most promising lower carbon energy options for transport, is being tested in three hydrogen fuel cell buses introduced in London in December 2004. This trial forms part of the EU-wide Clean Urban Transport for Europe (CUTE) demonstration project, which involves twenty-seven hydrogen fuel cell buses trialled for a period of two years in nine cities around Europe, including London.

Hydrogen fuel cell buses provide several environmental benefits. Firstly, hydrogen produces no emissions at point of use (the only by-product of hydrogen combustion is water vapour), thus reducing greenhouse gas emissions and local air pollution from buses. Secondly, 'fuel cells' (the electrochemical devices that run on hydrogen to power the vehicle) are more efficient than current engines. Thirdly, hydrogen fuel cell vehicles are silent when running, thus reducing noise pollution. Hydrogen can be produced from either traditional (hydrocarbon) or renewable sources of energy, although production from renewable sources is the preferred option, as this entails no carbon emissions during production.

Using the contingent valuation method this paper has two purposes: 1) to estimate the economic value of the environmental benefits of hydrogen fuel cell buses (namely reduction of emissions and noise pollution)[1] to London-based residents, and 2) to identify the determinants of willingness to pay (WTP) estimates using standard ordinary least squares (OLS) and quantile regression methods.

[1] This work forms part of the larger ACCEPTH2 project coordinated by the Environmental, Policy and Management Group (EPMG) at Imperial College London. This is a EU-funded collaboration between 5 cities worldwide: London (UK), Munich (Germany), Luxemburg, Perth (Western Australia) and California (US), and consists of a cross-continental comparative study of public acceptance of H2 FC buses before *and* after introduction, and an estimation of the economic value of their environmental

Quantile regression has been used in this study for several reasons. Firstly, it was considered that quantile regression might add value to the results of the standard OLS regression results. Classical OLS linear regression involves examining relationships between variable means, whereas quantile regression allows for examination of relationships between variables along the entire length of the conditional distribution (Koenker, 2003). This approach can therefore provide a more complete statistical picture of the relationships between variables. Secondly, quantile regression is robust to the presence of outliers or skewed tails, characteristic of the data for this study (Mello and Perrelli, 2003). This contrasts with OLS estimation, which is severely affected by outliers (Koenker and Hallock, 2001). Thirdly, there is a policy interest in understanding whether the variables determine lower and higher WTP values in the same way. Of particular interest is identifying who will benefit most from the introduction of hydrogen buses in London (assuming the higher the WTP estimates, the higher the benefit), and who will benefit least.

The rest of this paper is structured as follows: Section 2 reviews empirical studies of acceptance and preferences for environmental transport technologies including hydrogen; Section 3 presents the data collection methodology, Section 4 presents descriptive results and OLS regression results; Section 4.2 introduces the quantile regression model and results; Section 5 includes discussion and conclusions

Literature Review

Public Preferences for Cleaner Transport

There has been comparatively little work to date on valuing the environmental attributes of transport, such as impacts on air quality, noise levels and visual amenity, and what research has been done seems to indicate that environmental concerns are not important in the choice of transport technology. Ewing and Sarigöllü (1998) found that there was a large potential demand in Montreal for low emission vehicles, as long as the vehicles could compete with conventional cars in performance and vehicle

benefits. This paper specifically deals with estimation of the environmental benefits of hydrogen buses in London *before* the introduction of the hydrogen bus trial.

price. Running costs and emissions were not found to have a significant influence on vehicle-purchasing decisions. Similarly, Segal (1995) found the low running costs of electric vehicles to have little influence on the demand for these vehicles in California, whereas their high purchase price and refuelling times were significant influences on demand. Experimental studies by Kurani et al (1996) and Kurani et al (1995), using focus groups, vehicle trials and mail surveys, assessed the potential for electric vehicles in local household transportation. Home recharging was found to be the most highly valued attribute and environmentalism the least valued. Contrary to expectations, there was very little negative utility associated with reduced driving range (a characteristic of electric vehicles) although other studies (Cheron and Zins, 1997; Brownstone et al, 1996; Calfee, 1985) find range to be a key barrier to uptake of electric vehicles (followed by capital cost). In another experimental study by Turrentine et al (1992) respondents' attitudes were elicited, before and after test-driving alternative fuel vehicles, and it was found that members of environmental organisations did not show higher clean-vehicle purchasing intentions.

Of those studies that do report a correlation between environmental attitude and acceptance for cleaner transport, environmental concern is a weaker influence than price and performance (Chiu and Tzeng, 1999; Brownstone et al, 1996; Sperling et al, 1995; and also Mourato et al, 2003, in their long-term scenario). Only the study by Lossen et al (2003) finds that environmental attitudes significantly influence the acceptance of hydrogen transport. However, as noted by the author, the survey sample in this attitudinal study is highly unrepresentative, consisting of self-selected Internet users (71% male; 79% under 36 years; 87% in academia).

Public Preferences for Cleaner Buses

There very few studies specifically addressing the environmental attributes of buses: the only known article (Balassiano and White, 1997), investigates public attitudes towards compressed natural gas (CNG) buses compared to diesel buses in Rio de Janeiro. Results show a positive attitude towards the CNG buses, although actual bus use appeared not to change. As of yet, there have been no studies of willingness to

pay (WTP) for environmental attributes of buses (personal communication, Prof Peter White[2], September 2002).

Preferences for Hydrogen Vehicles

The only study to date to estimate the economic value of hydrogen fuel cell vehicles specifically was carried out by Mourato et al (2003). Using the contingent valuation method (CVM), the economic benefits of hydrogen fuel cell taxis to taxi drivers were estimated for (i) driving a hydrogen fuel cell taxi for a pilot project, and (ii) purchasing one later on, in an optimistic scenario of mass introduction. It was found that despite support for cleaner fuels and vehicles, taxi drivers' WTP (which ranged between £2900 and £3500 for participation in the pilot project) was influenced mainly by personal financial concerns (i.e. reduced running costs associated with the project). However, driver's WTP of a premium for production hydrogen fuel cell taxis in the long term was influenced by concerns about air pollution, education levels and knowledge about the technology itself. Another interesting finding in this study was the lack of concern over the safety of hydrogen fuelled vehicles, an issue that has been often cited by experts as a potential barrier to hydrogen vehicle uptake. Although Altmann and Graesel (1998) also found hydrogen safety not to be an issue, more studies will need to be undertaken to clarify this issue.

Studies of public *acceptance* of hydrogen vehicles (Lossen et al, 2003; Dinse, 2000; Dinse, 1999; Altmann and Graesel, 1998) indicate that despite weak knowledge about hydrogen as a fuel, there is a relatively high level of acceptance of hydrogen vehicles. It is important to note however that these findings are based on attitudinal studies, and as indicated by Gould and Golob (1998) acceptance levels in attitudinal surveys tend to be much higher than acceptance levels in experimental and stated preference surveys. Attitudes tend to reflect ideals and, crucially, imply no trade-offs between one's limited budget and securing cleaner transport alternatives (Kurani et al, 1996).

Method

In order to measure the monetary value of reduced emissions and noise pollution from hydrogen bus transport in London, a contingent valuation-based survey was used

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(Mitchell and Carson, 1989; Bateman et al, 2002). Contingent valuation methods (CVM) were developed within environmental economics as a means to place an economic value on environmental goods, which due to their public good nature, are not traded in the market. The method involves a questionnaire in which respondents are presented with a hypothetical (or 'contingent') market where the good or service in question can be traded (Mitchell and Carson, 1989). Respondents are then asked for their maximum willingness to pay (WTP) or minimum willingness to accept compensation (WTA) for a hypothetical change in the level of provision of the good. Contingent valuation assumes that stated WTP is a measure of respondents' underlying preferences, which are equivalent to Hicksian welfare measures (Mitchell and Carson, 1989).

A series of three focus groups were held during June 2003 to assist in the design of the pilot study and final questionnaire. The questionnaire comprised five sections (A to E). Section A established bus usage and attitudes towards existing buses in London. Section B explored perceptions of hydrogen, knowledge about and attitudes towards the development of hydrogen as a fuel for transport. Information on hydrogen as a fuel for transport and the CUTE hydrogen bus project were contained within this section, and attitudes were explored before and after giving respondents the information. Section C contained the contingent valuation section. Socio-economic characteristics were determined in Section D and environmental attitudes, knowledge and behaviour in Section E.

The questionnaire contained information on the advantages and disadvantages of hydrogen as a fuel for transport, and a brief description of the CUTE hydrogen bus project. The valuation section (Section C) then presented respondents with the following scenario: "*Suppose that there was a proposal to substitute the buses in the London transport system for hydrogen fuel cell buses. As I mentioned earlier, these hydrogen buses would emit zero air pollution, be less noisy and more efficient than conventional buses. However they would also be more costly to run".* Willingness to pay (WTP) was elicited using three different payment vehicles. The first (WTP_S) involved willingness to pay extra on top of a standard single bus fare (70pence in London). The second mechanism (WTP_M) was developed

during the focus group sessions in which many respondents were able to conceptualise extra fare payments on a monthly basis, rather than on a fare-by-fare basis. The third mechanism (WTP_X) involved annual increases in taxes (tax type not specified). This allowed the survey to capture WTP measures for non-bus users and freedom pass holders (free bus travel for over 60-year olds). These respondents were not asked for their WTP extra bus fare. The elicitation format used was a payment ladder. This involves asking respondents to choose a WTP amount from a series of amounts read out by the interviewer, starting at zero and increasing by discrete amounts to a maximum.

Using telephone numbers generated randomly using Excel, a total of 420 telephone interviews were carried out between 14th July and 2nd September 2003 with London-based residents. 6 questionnaires were dropped from the final analysis due to incompletion. Just under 50% of calls made were answered, and of these, 18% were completed the first time around and 40% completed in total (including call-backs). Average duration was about 25 minutes per survey.

Results and Discussion

4.1 Descriptive Results

Sample Characteristics

Table 1 presents summary statistics of key socio-economic, behavioural and attitudinal variables for the sample (n=414). The sample is biased towards respondents with high income (mean annual household income of £42,000[3], compared to London average of £37,000[4]) and education levels (more than two fifths have university degrees[5]). 48 respondents refused to state their income. Sample employment levels are also higher than the London average of 70.9% (Source: 1.2 Key Statistics for London, Office for National Statistics, www.statistics.gov.uk).

[3] Income categories were converted into currency figures by taking the mid-point interval for each income category, and £120,000 for the last open category.

4 Average annual income values obtained by multiplying weekly figures by 52 (weeks per year). Source: Focus on London (25th June 2003) Household income: London's exceeds UK average, (http://www.statistics.gov.uk/CCI/nugget.asp?ID=389&Pos=1&ColRank=2&Rank=1000)

[5] This proportion almost doubles the London average of 25% of the population with degrees, indicating possible self-selection bias of respondents to the survey.

INSERT TABLE 1 HERE

Three quarters (74%) of the sample consisted of bus users (i.e. have used a bus in the last 12 months). Of these, 62% use the bus at least once a week and 22% use the bus less than once a month. 35% of respondents had some form of season pass (weekly, monthly or annual), whilst 51% tended to buy single adult tickets (both 70p and £1) or daily travel cards. Attitudes towards fumes and noise from buses were negative with over four fifths of respondents rating these attributes as 'poor' or 'very poor'. Over three quarters of respondents agreed that: "*Solving environmental problems should be one of the top 3 priorities for public spending in London"* and 13% regularly donate to environmental organisations or charities.

Knowledge and Attitudes towards Hydrogen Vehicles

Over two fifths (45%) of respondents claim to have heard about hydrogen vehicles. The most common sources of information about H2 vehicles are television (34%) and newspapers/ magazines (31%). Initial attitudes towards hydrogen vehicles being introduced in London were elicited using a simple "support/oppose/need more information/don't care" scale. 35% of respondents support the introduction hydrogen vehicles, but most respondents (60% of sample) 'need more information.' Only one respondent out of the entire sample opposed hydrogen vehicles. Of those who had prior knowledge about H2 vehicles, 60% support hydrogen vehicles, whereas 37% still need more information to give an opinion. Of those who had no prior knowledge, 15% stated support for h2 vehicles. Reasons for support at this stage in the questionnaire are overwhelmingly environmental (33% mentioned "environment", "pollution" or "air quality" as the main reason for support). Only one respondent specifically mentioned greenhouse gas reduction as the main reason for support.

Once respondents had been provided with information about hydrogen, fuel cells, and the hydrogen fuel cell bus demonstration, they were asked whether they thought the following to be good ideas: 1) that London is trialing three hydrogen fuel cell buses, 2) to introduce hydrogen fuel cell buses in the public transport system on a large scale. Most respondents (93%) support the bus trial, although opposition has increased marginally to 7 respondents. Reasons given for support are mainly

associated with environmental issues (70% of sample). Other reasons for support include: "good to research new technologies and fuels" (12% of sample) and "reducing dependency on foreign oil" (2.5%). Support for the large-scale introduction of hydrogen fuel cell buses in London is significantly lower than support for the trial, with half of the sample saying it depends on 'safety' or 'results of the trial'.

Willingness to Pay (WTP) to have Hydrogen Buses in London

All paying bus-users (n=282) were asked how much they were willing to pay extra bus fare per single 70 pence fare. Reasons given by the 25 respondents (8.9% of bus users) who were not willing to pay extra were mostly protest responses[6], and excluded from the analysis. Respondents who had stated a positive value for the single fare payment vehicle (n=254) were then asked how much they would be willing to pay in extra fares every month to have hydrogen fuel cell buses introduced in London. Eleven respondents stated zero willingness to pay, however it was not possible to identify whether these were protest responses as no follow-up question was provided at this stage of the questionnaire. These zero values were left in the analysis. *All respondents* (n=414) were asked for their WTP extra taxes to support the introduction of hydrogen buses in London. 48.31% (n=200) stated zero WTP extra taxes to support the introduction of hydrogen buses. Of these, most (86%; n=172) were identified as protest responses[7] and removed from the analysis. Table 2 presents summary statistics for the estimated values for all three payment vehicles.

INSERT TABLE 2 ABOUT HERE

Results show that the present value of WTP extra fare per year calculated from the elicited monthly payments is substantially greater than WTP_X per year (£61.68 compared to £19.94). This represents over three times the directly elicited annual mean. This presents a possible case of temporal embedding, which occurs when a respondent is unable to properly differentiate between one-off payments and a series of payments. If temporal embedding is present in a valuation study, then the value of the one-off payment will be substantially less than the sum of the series of payments

[6] Protests to WTPSING specification include: *"bus fares are already expensive"* or *"I object to paying higher bus fares"*
[7] Protests responses include: "should be paid by bus users", "should be paid through other taxes or congestions charge", and "I object to paying more taxes" or "taxes are high enough as it is".

(Kahneman and Knetsch, 1992). However, in this study mean and median WTP extra fare per month calculated from single fare payments[8] are not significantly different than directly elicited WTP_M. This is also found when restricting the values to those provided by single or daily ticket holders, who are willing to pay higher amounts per single ticket than seasonal pass holders. Temporal embedding may therefore be dismissed as a factor influencing the WTP values elicited in this study.

It is more probable that the low WTP_X estimates are due to less positive attitudes towards tax-based payment vehicles compared to fare-based vehicles. The high proportion of respondents protesting against the tax-based mechanism (86% of 'zero' WTP_X responses identified as protest) appears to confirm this suggestion. Protest responses to fare-based payment vehicles were minimal (under 5% in both cases).

Regression Analysis

5.1 OLS Regression

Variables influencing respondent's willingness to pay for the introduction of hydrogen buses in London were determined using ordinary least squares regression (OLS) for all three payment mechanisms (single, monthly and annual (tax) payments). Regressors included in this valuation exercise are presented in Table 3. Regression results are presented in Table 4.

INSERT TABLE 3 ABOUT HERE

INSERT TABLE 4 ABOUT HERE

Preliminary inspection of results shows that the determinants of WTP values differ between payment vehicles. Indeed, income and environmental attitude are the only variables to significantly influence WTP values elicited via all three payment methods (although it must be noted that income is only significant at the 10% level for WTP_S). For example, age has a negative effect on the fare-based payment vehicles, yet a

[8] Calculated by taking mid-interval of TRIPNOS and multiplying by 4 to obtain approximate number of bus trips per month. This value is then multiplied by WTPSING to obtain monthly WTP values.

positive influence on WTP_X. Interpretation of the coefficients reveals that for every 10 years older the respondent is, willingness to pay decreases by 4 pence (6%) per single fare and increases by £11.20 extra tax per year. Attitudes towards taxation, or whether respondents actually pay tax (e.g. students, unemployed) may account for this changing relationship between WTP and age by payment vehicle[9]. However further research required. Also, gender appears to only influence WTP_X, but neither of the fare-based mechanisms. Interpretation of the coefficients suggests that male respondents are willing to pay £8.54 more tax than females to support introduction of hydrogen buses. As with the age variable, attitudes to payment vehicles might account for the fact that gender is only an influence on WTP_X. Education surprisingly has no influence on willingness to pay using any of the fare-based payment vehicles.

As was expected, bus usage was significant influence on fare-based payment methods. The more trips respondents make by bus, the less they are willing to pay per single ticket, and the more per monthly pass (although this latter relationship is not significant). Seasonal ticket users are significantly (at 10% level) willing to pay £1.27 more per month, than single or daily ticket users. Respondents' attitudes towards environmental attributes of existing buses have barely any influence on WTP. Attitudes to fumes however significantly influenced WTP_M, in the expected direction. Respondents who tend to donate to environmental groups or causes are willing to pay more per single fare than those who don't, but are not willing to pay extra monthly fare or tax. Finally, an interesting result is that respondents who have heard of hydrogen vehicles are willing to pay £1.47 extra fare per month, and £9.39 extra tax per year to support the introduction of hydrogen buses. This implies that the information currently available is positive.

Results of this study indicate that only the WTP_X model has any significant explanatory power (R_2=0.2). Regressions for both fare-based payment vehicles have produced low R_2 values, indicating weak relationships with the socio-economic, attitudinal and knowledge regressors. Even when the WTP_M regression is restricted to seasonal pass holders, who are expected to be able to conceptualise monthly increases more easily, the independent variables are largely insignificant. The low overall

[9] Correlations between age, protest towards WTPX and work status were carried out, but no significant relationships found.

predictability of these models however is not disheartening. This study is largely exploratory given the paucity of research into public preferences for hydrogen technologies, or public acceptance or preferences for the environmental attributes of buses. It is possible however that there are significant relationships between variables at different points along the distribution of the independent variable (WTP). Hence the results shall be analysed using quantile regressions.

5.2 Quantile Regression

5.2.1 Brief Introduction

OLS regression is based on the *mean* of the conditional distribution of the dependent variable, in this case WTP. This approach assumes that impacts of the independent variables are homogenous along the entire distribution of the dependent variable. However, this assumption may prove inadequate if indeed the independent variables influence parameters other than the mean (Koenker, 2003; Koenker and Bassett, 1978). Quantile regression methods provide a mechanism for estimating relationships based on the range of quantiles along the conditional distribution. In a willingness to pay (WTP) setting, the quantile regression model can be written as (Koenker and Bassett, 1978):

$$WTP_i = X_i ß_? + u_{i,?} \qquad \text{with } Quant_? (WTP_i \mid X_i) = X_i ß_? \qquad (1)$$

Where X_i is a vector of exogenous variables, and $ß_?$ is the vector of parameters that are being estimated. $Quant_? (WTP_i \mid X_i)$ denotes the ?th regression quantile of WTP_i given X_i. In order to obtain the ?th regression quantile, where $0<?<1$, linear programming methods are used to obtain a solution to the problem:

$$\underset{b_?}{\text{Min}} \left\{ ? \sum_{i:WTPi=Xiß} ? \mid WTP_i - X_i ß_? \mid + ? \sum_{i:WTPi<Xiß} (1-?) \mid WTP_i - X_i ß_? \mid \right\} \qquad (2)$$

where $b_?$ is the estimate of $ß_?$. The quantile regression estimator therefore minimises the weighed sum of the absolute value of the residuals. By varying ?, coefficients for

any quantile along the distribution of WTP can be estimated. The coefficients in quantile regression can be interpreted in a similar way to OLS coefficient estimates. For example, in a regression of income on WTP, the coefficient on income at the 25th quantile (?=0.25) gives the marginal change in WTP given a marginal change in income, for respondents in the bottom quarter of the conditional distribution of WTP.

Quantile regression has been used in economics to analyse returns to education (Bauer and Haisken-DeNew, 2001), determinants of wages and wage inequality (Martins and Pereira, 2003) and income convergence in growth equations (Mello and Perrelli, 2003). However, there appear to be no studies applying quantile regression techniques to WTP estimates. By applying quantile regression methods to WTP for hydrogen buses in London, this paper aims to provide an indication of the added value of using quantile regression in addition to the standard OLS techniques to investigate determinants of WTP.

5.2.2 Quantile Regression Results

Table Q1 shows the results of quantile regressions at selected quantiles for the three payment vehicles. These results will be discussed by payment vehicle.

INSERT TABLES Q1, Q2 and Q3 ABOUT HERE

WTP Single Fare

As the results show, the effects of the explanatory variables tend to vary significantly along the distribution of WTP_S. For example, the plot of the coefficient on male suggests that the effect of gender on WTP_S changes direction throughout the distribution (see Fig Q1). Thus males are willing to pay marginally more than females in the lower quantiles (about 2 pence per single bus fare), but less than females between the 40th and 80th quantiles (just under 2 pence less). Similar variations in effects are found for the quantile regression estimates for age, university education, bus usae and attitudes. In fact, only the quantile regression estimates for income and environmental attitude (excepting the coefficient at the 5th quantile) are relatively stable around the OLS mean.

Overall, results indicate that, below the median value of 30pence, WTP_S is significantly related to environmental attitude, age, income and bus usage, whereas higher WTP_S values are determined by age, prior knowledge about hydrogen and environmental behaviour. Note that prior knowledge about hydrogen was not significant in the OLS regression. Quantile regression estimates however reveal that it is significant at the 80^{th} quantile, indicating that those with prior knowledge are willing to pay about 6pence more than those with no prior knowledge. This effect is almost is about three times the OLS estimate.

WTP Extra Fare per Month (WTP_M*)*

Results for the quantile regression on WTP_M are particularly interesting, as variables that were not identified as significant in the OLS regression are significant at different quantiles of the WTP_M distribution. These variables include gender, education (at the 30^{th} quantile), bus use frequency or donations to environmental organisations. For example, the OLS regression of WTP_M indicated that the only socio-economic variable to have any influence on WTP was income, whereas quantile regression estimates reveal that males at the lower quantiles (5^{th} and 10^{th}) are significantly willing to pay more than females, and respondents with lower education levels (at 5^{th} and 30^{th} quantiles) are willing to pay more than those with higher education levels. Bus use frequency and the environmental behaviour indicator (DONATE) are also significant at the lower quantiles.

The quantile regression of WTP_M demonstrates the added value of using quantile regression analysis in addition to standard regression techniques. Although the OLS regression did not identify male, education, tripnos or DONATE as significant influences on WTP, quantile regression indicated that they were indeed significant at certain quantiles. Interestingly they were all significant at the left hand tail of the distribution, which can give more insight into the range of WTP values elicited from contingent valuation surveys. It is often the case that outliers are removed or data is truncated to carry out the OLS regressions. These results show that removal of such data may inhibit a better understanding of the full range of responses.

WTP Extra Tax

As with the WTP_S and WTP_M specifications, the income effect on WTP_X increases along the length of the distribution. The OLS coefficient estimate indicates that for every £10,000 increase in household annual income, WTP extra tax per year is about £2. However, this amount is much lower in the left hand tail of the distribution, and rises sharply in the higher quantiles where the income effect reaches up to three times the OLS estimate. At the 90^{th} quantile, income is the only significant influence on WTP, indicating that the highest value is not necessarily associated with the highest benefit, but possibly reflects an ability to pay. Males are WTP substantially more than females (£8.54 more), according to OLS estimate. However the disparity is smaller in the lower quantiles, and rises steeply beyond the median to a maximum value of about £14 in the 60^{th} quantile. Beyond this point the coefficient falls again to below the OLS estimate, although it is not significant. University education also has a positive effect on WTP_X although it is only significant at the 20^{th} and 30^{th} quantiles, at values of just under £4 extra tax for respondents with university education. This result contrasts with the negative effect of university education[10] on the fare-based payment vehicles. Interestingly, age (entered as a quandratic function) is not significant at any quantile, despite being significant at the 5% level in the OLS model.

Environmental attitude has an increasing impact on WTP_X along it's distribution, although it is not significant at the right tail, indicating that at higher quantiles, environmental attitude is not a driving force. It is however a significant determinant of lower WTP_X values. This finding is similar to results for the WTP_S and WTP_M specifications, where environmental attitude is significant at the lower and central quantiles. Another finding that parallels results for the other two payment vehicles is the impact of prior knowledge on WTP. Prior knowledge of hydrogen vehicles has a significant and positive effect at the higher quantiles of the distribution, where WTP extra tax is over £16 (almost double the OLS estimate).

Conclusion

This study has shown that there is a positive willingness to pay to support the introduction of hydrogen fuel cell buses in London, although the nature of the

[10] In the WTPMNTH specification, LOWEDUC is used as the education variable, and the coefficient on this is positive, indicating that the coefficient on UNIVEDUC would be negative.

payment vehicle used to elicit these economic values appears to affect the WTP results significantly. For example, older respondents appear to be willing to pay less extra bus fare compared yet more extra tax. This makes the process of providing policy-relevant information about *who* benefits most and *who* benefits least from projects, such as the hydrogen bus demonstration project, very difficult. Quantile regression results further highlight this problem by showing that determinants of WTP not only differ between payment vehicles but along the distributions of different payment vehicles.

Quantile regression estimates also show that WTP of the highest bidders is not determined by the same variables that influence WTP of the lowest bidders. For example, lowest WTP_S is determined by environmental attitudes, whereas highest WTP_S is determined by environmental behaviour, indicating that attitudes create positive WTP per single fare but do not drive higher bids. In contrast, environmental behaviour is a determinant of lower WTP_M values whereas environmental attitude only becomes significant in the central part of the distribution. Of particular interest is the influence of prior knowledge on all three specifications. Various socio-economic and attitudinal variables influence the lower WTP values, but higher values are determined by prior knowledge across all three payment vehicles. Remembering that two fifths of respondents with prior knowledge still 'needed more information' to have an opinion about hydrogen vehicles (Section XX), it is improbable that the high WTP values were based solely on prior knowledge. It is possible that attitudes tended towards positive rather than negative, and respondents simply needed more information to 'make their minds up'. It is also possible that that utility is also derived from a sense of 'personal relevance' with the subject matter hence driving up the WTP values. These are interesting issues that require further investigation.

Overall, this study shows that there are substantial information gains to be had by using quantile regression techniques in addition to standard OLS techniques, for analysing contingent valuation data. As results for the WTP_M specification show, some variables that were not significant in the OLS regression emerge as significant at particular quantiles of the WTP distribution. Interestingly they were all significant at the tails of the distribution, which can give more insight into the range of WTP values elicited from contingent valuation surveys. It is often the case that outliers are

removed or data is truncated to carry out the OLS regressions. These results show that removal of such data may inhibit a better understanding of the full range of responses.

Table 1: Socio-economic Characteristics of Bus Users and Non-Bus Users

Variable	Levels	All Respondents (n=414)	Bus Users (n=308)	Non-bus Users (n=106)	p>t
Sex (% male)		41.3	41.9	39.6	0.6844
Age (mean)		39	38	43	0.0004+
Highest level of education (% respondents)	Primary	1.21	0.97	1.88	0.4593
	Secondary yr 10	12.32	9.1	21.7	0.0006+
	Secondary yr 12	25.85	26.6	23.58	0.5388
	Professional Qualif.	14.49	13.63	16.98	0.40
	Univ. Degree (UG)	36.23	38.3	30.2	0.1341
	Univ. Degree (PG)	5.90	11.36	5.66	0.094*
	University educ (%)	46.14	49.68	35.85	0.0137**
Work Status (% respondents)	Self-employed	4.83	4.87	4.71	0.9496
	Employed (>30 hrs/wk)	64.97	63.3	69.8	0.2273
	Employed (<30 hrs/wk)	10.63	11.68	5.55	0.2338
	Student	5.8	6.81	2.83	0.1303
	Retired	7.25	6.49	9.43	0.3150
	All other (unemployed, housewife, disabled)	6.53	6.81	5.66	0.6780
Annual Income (mean £)		41738.49	41241	43241.76	0.1593
Car ownership (% owning car)		68.12	61.36	87.74	0.00+

* Significant at 10% level
**Significant at 5% level
+ Significant at 1% level

Table 2: Summary Statistics for WTP to Support Hydrogen Bus Introduction

	WTP_S	WTP_M #	WTP_X *
% resps positive WTP	254	245	214
% WTP=0 (valid)	6	14	28
% WTP=0 (protests)	22	-	172
Mean WTP (£) (with protests)	0.25	5.57	17.67
(s.d.)	(0.20)	(5.7)	(62.15)
Mean WTP (£) (no protests)	0.27	-	30.23
(s.d.)	(0.194)		(78.98)
Mean WTP (£) (no protests or outliers) (s.d.)	-	5.14	19.94
		(4.44)	(25.71)
Median WTP (£) (no protests)	0.30	5	10.00
Minimum/Maximum	0/1.50	0/20	0/1500

* Adjusted values (8 outliers (1.5% sample) removed)
# Protests were not identified for this question, so all zero values were kept in the analysis; 4 outliers removed (1.5% of sample).

Table 3: Variables Included in OLS Regressions

VARIABLE	Description
WTP_S	WTP extra per single 70p bus fare to support introduction of H2 buses in London
WTP_M	WTP extra bus fare on a monthly basis to support introduction of H2 buses in London
WTP_X	WTP extra annual tax to support introduction of H2 buses in London
YADJ	Income taken as mid interval of income levels (and divided by 10000)
MALE	Dummy indicating 1=male/ 0=female
UNIVEDUC	Dummy for university education: 1=yes/ 0=no
AGE	Respondent's age
AGE2	Square of respondent's age
TRIPNOS2	Bus use frequency (from 1-less than once a month to 6- over 14 times a week)
SEASPASS	Dummy for whether respondent holds seasonal (weekly, monthly or annual) bus pass: 1=yes/ 0=no
RATEFUME	Attitude towards level of fumes produced by existing buses (from 1-very poor to 5-very good)
RATENOISE	Attitude towards level of noise produced by existing buses (from 1-very poor to 5-very good)
H2KNOW2	Dummy for knowledge about H2 vehicles: 1=yes/ 0=no
ENVATT1	Environmental attitude indicator (from 1-strongly disagree to 5-strongly agree)
DONATE	Indicator of how often a respondent donates to environmental groups/ orgs (from 1-never to 5-very often)

Table 4: WTP Extra to Support Introduction of Hydrogen Buses in London

	WTPS (n=254)#		WTPM (n=245)#		WTPX (n=242) #	
	coeff	t-ratio	coeff	t-ratio	coeff	t-ratio
YADJ	0.0841 (0.0487)	1.73*	0.285 (0.14)	2.03**	2.234 (0.826)	2.71**
AGE	-0.0041 (0.0013)	-3.19**	-0.0274528 (0.0335741)	-0.82	1.120076 (0.5219633)	2.15**
AGE2	-	-	-	-	-0.011637 (0.0051981)	-2.24**
MALE	-0.0087 (0.0256)	-0.34	0.7050106 (0.7733505)	0.91	8.540557 (3.437834)	2.48**
UNIVEDUC	-0.0129 (0.0249)	-0.52	-0.3022489 (0.6540635)	-0.46	4.789015 (3.317935)	1.44
TRIPNOS2	-0.03803 (0.0170)	-2.24**	0.1078818 (0.5254754)	0.21	-	-
SEASPASS	-	-	1.26716 (0.7694829)	1.65*	-	-
RATEFUME	0.0018452 (0.0176847)	0.10	-0.7889385 (0.3814226)	-2.07*	-	-
RATENOISE	-0.004344 (0.0175768)	-0.25	0.2886591 (0.3739479)	0.77	-	-
H2KNOW2	0.0319854 (.0269335)	1.19	1.471277 (0.8020882)	1.83*	9.399058 (3.785533)	2.48**
ENVATT1	0.0409572 (0.0153465)	2.67**	1.150319 (0.4310686)	2.67**	3.611165 (2.067801)	1.75*
DONATE	0.036759 (0.0139175)	2.64**	0.4429782 (0.3679095)	1.20	-	-
Constant	0.1794856 (0.0818594)	2.19**	-0.4926877 2.315937	-0.21	-36.42522 (14.4021)	-2.53**
R-2	0.1423		0.1158		0.2008	

Adjusted values (outliers and protests removed)
** Significant at 5% level / * significant at 10% level

Table Q1: Quantile regression estimates for WTP_S (coefficients and t-stats)

	0.05		0.2		0.5		0.8		0.9	
	coeff	t-value	coeff	t-value	coeff	t-value	coeff	t-value	coeff	t-value
yadj	0.0012	0.16	0.0068	1.48	0.0069	1.69*	0.0065	1.25	0.0197	1.39
age	-0.0022	-1.26	-0.0020	-1.34	-0.0021	-1.89*	-0.0036	-2.32**	-0.0061	-1.45
male	0.0185	0.46	0.0170	0.57	-0.0162	-0.69	-0.00317	-0.1	0.016607	0.22
univeduc	0.0015	0.04	-0.0219	-0.77	-0.0027	-0.12	-0.0471	-1.44	-0.0529	-0.72
tripnos2	0.0085	0.37	-0.0163	-0.93	-0.0393	-2.65*	-0.0280	-1.33	-0.018	-0.34
ratefume	0.0017	0.12	0.0062	0.32	0.0078	0.53	0.0033	0.17	0.0278	0.53
ratenoise	0.0095	0.47	-0.0166	-0.83	0.0030	0.2	-0.0018	-0.09	-0.02132	-0.37
h2know2	-0.0096	-0.23	0.0278	0.96	0.0066	0.29	0.0636	1.96**	0.0888	1.11
envatt1	-0.0011	-0.09	0.0446	2.74**	0.0376	2.8**	0.0382	1.77*	0.0436	0.81
donate	0.0034	0.21	0.0034	0.29	0.0133	1.38	0.0502	3.57**	0.0742	1.97**
constant	0.0907	1.16	0.0398	0.44	0.1306	1.67*	0.2383	1.95*	0.2531	0.83
R2	0.081		0.045		0.037		0.069		0.18	

Quantile regression results for the 5^{th} decile are reported in the WTP_S specification because there was no data at the 10^{th} decile

Table Q2: Quantile Regression for WTPM (coefficients and t-stats)

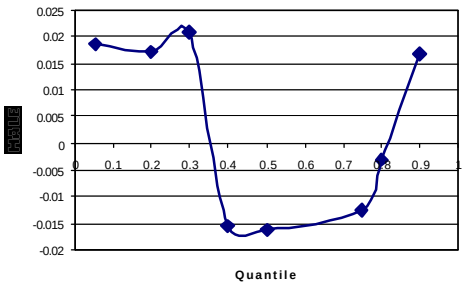
	0.10		0.20		0.50		0.80		0.9000	
	coeff	t-value	coeff	t-value	coeff	t-value	coeff	t-value	coeff	t-value
yadj	0.1241	1.50	0.1003	1.20	0.1481	1.59	0.3269	1.67*	0.3680	1.14
age	-0.0033	-0.13	-0.0263	-1.09	-0.0039	-0.15	-0.0052	-0.09	-0.0832	-0.71
male	1.0229	1.84*	0.5051	1.01	0.0607	0.11	1.1837	1.04	2.1203	0.98
loweduc	1.3915	1.64	1.2935	1.42	0.9715	0.97	2.9682	1.60	2.3028	0.60
tripnos2	0.7799	2.24**	0.8856	2.67**	0.4670	1.23	-0.5924	-0.63	-0.6674	-0.35
season	-0.1152	-0.21	-0.0866	-0.16	0.9418	1.54	0.3430	0.24	2.2945	0.83
ratefume	-0.2405	-0.76	-0.0349	-0.14	-0.6064	-1.79*	-0.7521	-1.07	-2.6843	-2.07**
ratenoise	-0.0113	-0.03	-0.0247	-0.08	0.2689	0.78	0.1332	0.20	0.3802	0.28
h2know2	-0.0960	-0.18	0.2453	0.50	0.6395	1.21	2.9720	2.60**	4.4061	1.96**
envatt1	0.1478	0.55	0.5529	2.18**	0.6143	1.98**	0.7516	1.05	0.9111	0.56
donate	0.4365	1.91*	0.4816	2.30**	0.1433	0.64	0.3775	0.75	1.1113	0.95
_cons	-1.3601	-1.04	-1.5905	-1.31	0.5463	0.31	3.1129	0.87	9.2660	1.29
R-2	0.0818		0.0737		0.0470		0.0844		0.0988	

Table Q3: Qreg Results for WTPX

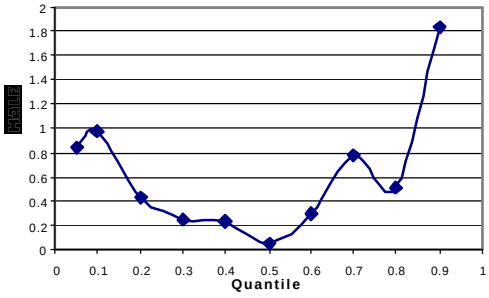
	0.10		0.20		0.50		0.80		0.90	
	coeff	t-value	coeff	t-value	coeff	t-value	coeff	t-value	coeff	t-value
yadj	0.1538	1.33	0.4349	1.83*	1.2120	2.19**	4.3356	2.22**	8.8353	1.8*
age	0.0239	0.16	0.1585	0.78	0.2407	0.42	1.4203	0.72	2.3155	0.4
age2	-0.0002	-0.11	-0.0016	-0.79	-0.0028	-0.47	-0.0148	-0.67	-0.0250	-0.38
male	0.8676	1.07	2.6728	2.13**	7.2089	2.32**	7.5705	0.76	-2.2439	-0.09
univeduc	0.7071	0.79	3.2704	2.61**	2.7972	0.9	5.0703	0.52	6.9066	0.3
h2know2	0.4840	0.53	1.8744	1.44	7.7544	2.45**	17.4230	1.69*	19.3929	0.7
envatt1	0.7667	1.93*	1.3122	1.86*	2.4917	1.39	6.0031	0.95	7.1858	0.48
constant	-4.1315	-1.13	-10.063	-1.86	-12.683	-0.9	-45.744	-0.97	-61.9195	-0.45
R-2	0.01		0.04		0.05		0.13		0.15	

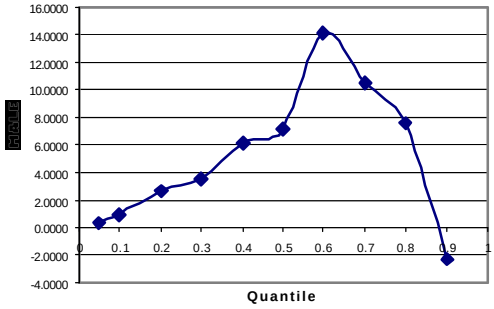
Fig Q1: Comparing Impact of Male on WTPS, WTPM and WTPX across the Distributions

Plot 1: Coefficient of Male on WTPS



Plot2: Coefficient of Male on WTPM





Plot 3: Coefficient of Male on WTPX

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